

What is claimed is:

1. An apparatus for extracting and sequestering CO₂ from a gas stream,
comprising:
a reactor vessel ;
5 an aqueous solution;
means for introducing said gas stream into said reactor vessel;
carbonate disposed in said reactor vessel, wherein said carbonate is of the form
X(CO₃)_m wherein X is any element or combination of elements that can
chemically bond with a carbonate group or its multiple, wherein at least one said
10 element is a group IA, IIA, IIIA, IVA, IB, IIB, IIIB, IVB, VB, VIB, VIIB, or
VIIIB element of the periodic table, and wherein m is a stoichiometrically
determined positive integer;
means for hydrating said CO₂ with said aqueous solution to form carbonic acid,
thereby resulting in a CO₂-depleted gas stream;
15 means for removing said CO₂-depleted gas stream from said reactor vessel;
means for reacting said carbonate with said carbonic acid to form a waste stream
solution of metal ions and bicarbonate;
means for removing said waste stream solution from said reactor vessel;
a disposal site:
20 means for pre-treating said waste stream solution to reduce the amount of CO₂
outgassing and carbonate precipitation that may occur after said waste stream
solution is released into said disposal site; and
means for releasing said pretreated waste stream solution into said disposal site.

2. The apparatus as recited in claim 1 wherein:

said pre-treating means comprises CO₂ degassing means selected from the group consisting of means for allowing said waste stream solution to degas CO₂ to an overlying headspace whose pCO₂ is less than that of said waste stream solution; means for purging said waste stream with a gas stream whose pCO₂ is less than that of the waste stream; and means for applying a partial vacuum to the headspace above the waste stream.

- 10 3. The apparatus as recited in claim 1 wherein:

said pre-treating means comprises means for diluting said waste stream solution with a second solution that is undersaturated with respect to CO₂, carbonate ions or both CO₂ and carbonate ions.

- 15 4. The apparatus as recited in claim 1 wherein:

said pre-treating means comprises means for adding chemical additives which impede carbonate precipitation, said chemical additives being selected from the group consisting of phosphate, metals, and organic compounds, said organic compounds being selected from the group consisting of EDTA, humic substances, aromatic acids, citrate, malate, pyruvate, glycelglycerine, glycogen, arginine, glutamate, glycine, glycoprotein succinate, taurine, chondroitin sulfate, galactose, dextrose and acetate.

5. The apparatus as recited in claim 1 wherein:

said pre-treating means comprises ion exchange means for exchanging at least a portion of the Ca^{2+} cations present in said waste solution with exchange cations which when balanced by the CO_3^{2-} anions present in the waste solution exhibit greater solubility and less propensity for precipitation than does CaCO_3 .

6. The apparatus as recited in claim 5 wherein:

said ion exchange means comprises passing said waste stream solution through an ion exchange column, with said column containing Na^+ exchange ions.

7. The apparatus as recited in claim 1 wherein:

said pre-treating means comprises ion exchange means for exchanging at least a portion of the CO_3^{2-} anions present in said waste solution with other anions.

8. The apparatus as recited in claim 7 wherein:

said ion exchange means comprises passing said waste solution through an ion exchange column containing Cl^- anions.

9. The apparatus as recited in claim 1 wherein:

said pre-treating means comprises means for increasing the density of said waste stream solution.

10. The apparatus as recited in claim 1 wherein:

said disposal site comprises a large body of water that is either freshwater or seawater.

11. The apparatus as recited in claim 10 wherein:

5 the pCO₂ of said body of water at the point of release of waste stream solution is less than that of said waste stream solution.

12. The apparatus as recited in claim 10 wherein:

10 said releasing means comprises means for releasing said waste stream solution at a depth sufficient for mixing and dilution of said waste stream solution with said body of water to occur.

13. The apparatus as recited in claim 10 wherein:

15 said releasing means comprises means for releasing said waste stream solution at a depth wherein the pressure and temperature existent at said depth is sufficient to impede CO₂ outgassing to the atmosphere and carbonate precipitation.

14. The apparatus as recited in claim 10 wherein:

20 said large body of water is either a sea or ocean; and
said releasing means causes said waste stream solution to be released below the pycnocline.

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15. The apparatus as recited in claim 10 wherein:

said large body of water is either a sea or ocean; and

said releasing means causes said waste stream solution to be released in the vicinity of a reef, above the pycnocline.

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16. The apparatus as recited in claim 10 wherein:

said disposal site is a body of surface seawater having sufficient constituents that serve to impede carbonate precipitation, said constituents being phosphate, Mg^{2+} ions, or phosphate and Mg^{2+} ions.

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17. The apparatus as recited in claim 10 wherein:

said disposal site is a large body of surface seawater having sufficient organic compounds that serve to at least partially impede carbonate precipitation, said organic compounds selected from the group consisting of humic substances, aromatic acids, citrate, malate, pyruvate, glycelglycerine, glycogen, arginine, glutamate, glycine, glycoprotein succinate, taurine, chondroitin sulfate, galactose, dextrose and acetate.

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18. A method of extracting and sequestering CO_2 from a gas stream, said method comprising the steps of:

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hydrating said CO_2 in said gas stream with an aqueous solution to form carbonic acid, thereby resulting in a CO_2 -depleted gas stream;

reacting said carbonic acid with carbonate to form a waste stream solution of

metal ions and bicarbonate, wherein said carbonate is of the form $X(\text{CO}_3)_m$ wherein X is any element or combination of elements that can chemically bond with a carbonate group or its multiple, wherein at least one said element is a group IA, IIA, IIIA, IVA, IB, IIB, IIIB, IVB, VB, VIB, VIIB, or VIIIB element of the periodic table, and wherein m is a stoichiometrically determined positive integer;

pre-treating said waste stream solution to reduce the amount of CO_2 outgassing and carbonate precipitation that may occur after said waste stream solution is released into a disposal site; and

releasing said pre-treated waste stream solution into said disposal site.

19. The method as recited in claim 18 wherein:

said pre-treating step comprises a CO_2 degassing step selected from the group consisting of allowing said waste stream solution to degas CO_2 to an overlying headspace whose $p\text{CO}_2$ is less than that of said waste stream solution; purging said waste stream with a gas stream whose $p\text{CO}_2$ is less than that of the waste stream; and applying a partial vacuum to the headspace above the waste stream.

20. The apparatus as recited in claim 18 wherein:

said pre-treating step comprises diluting said waste stream solution with a second solution that is undersaturated with respect to CO_2 , carbonate ions, or both CO_2 and carbonate ions.

21. The apparatus as recited in claim 18 wherein:

said pre-treating step comprises adding chemical additives which impede carbonate precipitation, said chemical additives being selected from the group consisting of phosphate, metals, and organic compounds, said organic compounds being selected from the group consisting of EDTA, humic substances, aromatic acids, citrate, malate, pyruvate, glycelglycerine, glycogen, arginine, glutamate, glycine, glycoprotein succinate, taurine, chondroitin sulfate, galactose, dextrose and acetate.

22. The method as recited in claim 18 wherein:

said pre-treating step comprises exchanging at least a portion of the Ca^{2+} cations present in said waste solution with exchange cations which when balanced by the CO_3^{2-} anions exhibit greater solubility and less propensity for precipitation than does CaCO_3 .

23. The method as recited in claim 22 wherein:

said cation exchanging step comprises passing said waste stream solution through an ion exchange column, with said column containing Na^+ exchange ions.

24. The apparatus as recited in claim 18 wherein:

said pre-treating step comprises exchanging at least a portion of the CO_3^{2-} anions present in said waste solution with other anions.

25. The apparatus as recited in claim 24 wherein:

said anion exchanging step comprises passing said waste solution through an ion exchange column containing Cl^- anions.

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26. The method as recited in claim 18 wherein:

said pre-treating step comprises increasing the density of said waste stream solution.

10 27. The method as recited in claim 18 wherein:

said disposal site comprises a body of water that is either freshwater or seawater.

28. The method as recited in claim 27 wherein:

15 the pCO_2 of said body of water at the point of release of waste stream solution is less than that of said waste stream solution.

29. The method as recited in claim 27 wherein:

20 said releasing step comprises releasing said waste stream solution at a depth sufficient for mixing of said waste stream solution with said body of water to occur.

30. The method as recited in claim 27 wherein:

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said releasing step comprises releasing said waste stream solution at a depth wherein the pressure and temperature existent at said depth is sufficient to impede CO₂ outgassing to the atmosphere and carbonate precipitation.

5 31. The method as recited in claim 27 wherein:

said large body of water is either a sea or ocean; and

said releasing step comprises releasing said waste stream solution below the pycnocline.

10 32. The method as recited in claim 27 wherein:

said large body of water is either a sea or ocean; and

said releasing step comprises releasing said waste stream solution in the vicinity of a reef, above the pycnocline.

15 33. The method as recited in claim 27 wherein:

said disposal site is a body of surface seawater having sufficient constituents that serve to impede carbonate precipitation, said constituents being phosphate, Mg²⁺ ions, or phosphate and Mg²⁺ ions.

20 34. The method as recited in claim 27 wherein:

said disposal site is a body of surface seawater having sufficient organic compounds that serve to impede carbonate precipitation, said organic compounds selected from the group consisting of humic substances, aromatic

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acids, citrate, malate, pyruvate, glycelglycerine, glycogen, arginine, glutamate,
glycine, glycoprotein succinate, taurine, chondroitin sulfate, galactose, dextrose
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